NASA Crew Personal Active Dosimeters (CPADs)

Leveraging Novel Terrestrial Personal Radiation Monitoring Capabilities for Space Exploration

TCC Radiation Technologies Event

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1) Novel Capabilities in Terrestrial Personal Radiation Dosimeters Yet Unused in Space

- Currently used NASA personal dosimeters (ISS): **Passive dosimeters**
  * **To be returned to ground** upon mission completion for analysis
  * **No in-flight exposure information**
  * Integral exposure information over entire mission, **no time resolution**

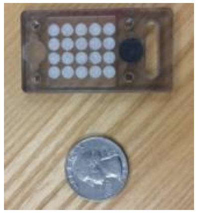
- Novel capabilities in terrestrial personal dosimeters:
  * **Active dosimeters**: configurable/autonomous recording of radiation exposure and internal storing of data
  * **Displays** for immediate user exposure feedback
  * **Wireless data transmission**

Opportunities to enhance Crew personal dosimetry with new features in terrestrial dosimeters

2) Technology Need for Exploration Mission 2 and Beyond

- **Requirements**: Need for wearable **personal active dosimetry**, capable of:
1) Measuring **time resolved** and time integrated absorbed dose
2) Operating for 30 days without being charged or requiring data download
3) Being read out by the crew via a **display on the dosimeter**

Requirement not met with existing NASA radiation hardware (passive dosimeters)



Space Radiation Analysis Group (SRAG, SD2) develops
COTS-based Crew Active Personal Dosimeters (CPADs) to meet requirements

- Derived requirements from intent of basic requirements:

a. Inobtrusiveness to Crew during mission operations

@ To minimize health risk projection uncertainties, CPADs to be worn at all times
@ CPADs need to be changed in all garment changes
@ Any additionally required Crew interaction to be avoided (e.g. data Xfer, power)

b. Accurate detection of space radiation environment (charged particles)

3) Market Survey/Technology Downselect

- **Use COTS products/base to minimize resource footprint of project**
  * Conduct **Market Survey** and **Technology Downselect**:
    @ Review COTS radiation detection technology options
    @ Identify most suitable radiation detection technology/implementation and vendor

- Apply basic selections to **identify/downselect COTS candidate dosimeters**:

  Action a): Identify dosimeters with needed features (keeps development gap small):
    @ Ready-to-purchase, packaged products (no research papers/components)
    @ **Battery powered**
    @ Capable of **record time-stamped dose**
    @ **Readout via common interface to laptop**
    @ **Small (<100 cm^3) & lightweight (<100g)**

→ **Result a)** Selected **2 Direct Ion Storage and 3 Silicon Diode COTS dosimeter candidates**

3) Market Survey/Technology Downselect

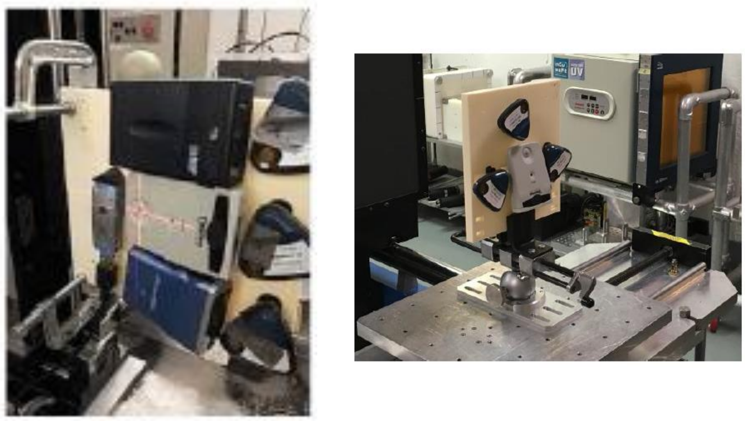
Candidate Detection Technology	Comment
Silicon diodes	Established (30 yrs), low power, small size, rugged; calibration potentially LET/energy dependent; used by IPs (ESA, JAXA)
Direct Ion Storage (DIS)	Established (20 yrs), low power, small size, rugged; used by IPs (ESA)
CsI(Ti) crystals	Too high power consumption, charged particle response probably not adequate
GM tubes	Only counter, charged particle response not adequate
Ionization chambers	Too large, too high power
MOSFET	No packaged product available; sensitivity probably not adequate; used by IPs (ESA)

Cand. Company, Product	Technology	Comment	Acquisition Status
Mirion, Instadose 1	DIS	No time resolved recording	Loaned for DIS assessment
Mirion, Instadose 2	DIS	Fulfills all criteria; pre-release beta hardware	Courtesy from Mirion
Mirion, DMC 3000	Si diode	Fulfills all criteria	Purchased
Thermo Fisher Scientific, EPD	Si diode	Fulfills all criteria (memory limit on dose storage)	Purchased
Fuji Electric Co, NRF-30	Si diode	Fulfills all criteria (no zero suppression in dose reads)	Purchased

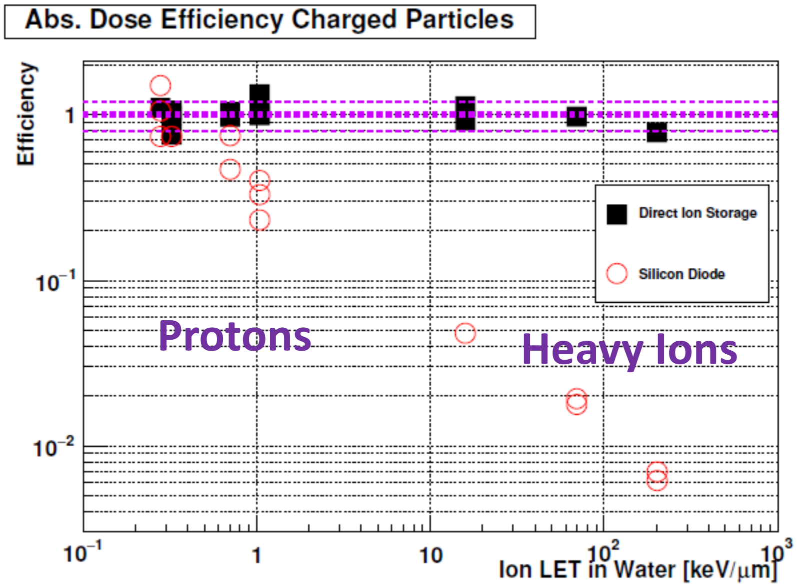
4) Technology Downselect

Action b) Test dosimeter candidates in space-relevant charged particle radiation fields

Result b) Tests selected Mirion DIS as sole feasible COTS technology & implementation



Radiation Testing @ TRIUMF, NSRL



- Mirion Technologies holds patents on DIS technology
  -> Selected as sole source vendor

5) CPAD Development Core MPCV Requirements

- Flow high level requirements to functional level to formulate development contract
- Leverage existing COTS features with additional new features to meet all CPAD requirements

MIRION TECHNOLOGIES

MIRION TECHNOLOGIES

= **CPAD**

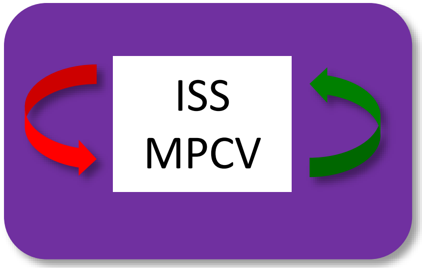
- MPCV Operations Requirements

Category	Flowed Down Requirement	Comment
Size/form factor, weight	Within 20% if Instadose 1: < 3 x 1 0.6”; < 50 g	Close to existing
Battery	Life 30+90 days, capacity < 200mAh	Exceeded by existing
Data storage	>= 4500 points	Exceeded by existing
	‘Dynamic read’: only record dose if beyond 20 muGy resolution (at most once per minute)	New feature (exists in industry)
Non-shatterable display	Display cumulative absorbed dose since mission start and dose over last 10 minutes (‘rate’)	New feature (exists in industry)
Bluetooth Wireless Data Transmission	Retain	Exceeding by existing, too costly to remove from design
Reset buttons for display and BLE processor		New feature (exists in industry)

6) Requirement Extension Leveraging Synergy between ISS and MPCV Programs

- **Benefits for ISS Program** from use of CPADs as operational personal dosimeters:
    * **Reduced ground processing cost/time**
    * Reduced up-down logistics
    * Near real-time data availability
- **Benefits for MPCV Program**: ISS agreed to fund **2017 Technology Demonstration Mission** with opportunity to validate derived requirements from intent of basic requirements (inobtrusiveness to Crew, accurate space radiation measurement)

Test bed for exploration



Exploration tech use on ISS

- ISS Additional Operations Requirements

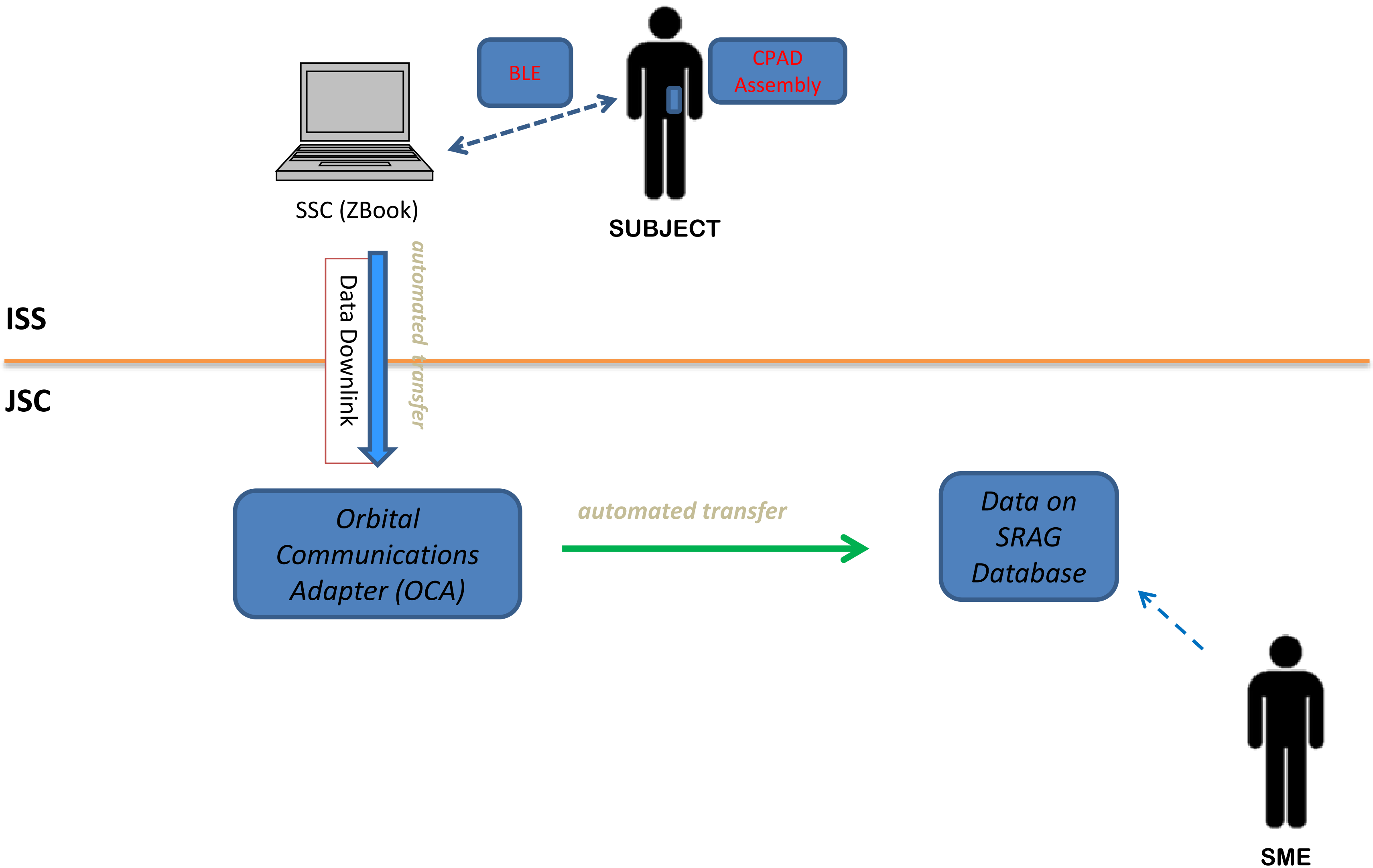
Category	Flowed Down Requirement	Comment
Battery compartment	Tool-free accessibility	New feature (exists in industry)
Battery	Life 8 months, capacity < 200mAh	Exceeded by existing
Bluetooth Wireless Data Transmission	Autonomous data transfer to webserver, transmission quality assurance, databasing	Exceeding by existing

7) CPAD Near-/Mid-Term Project Schedule

- **Accelerated schedule** due to use of COTS base and vendor:
  * 8/26/16 Contract start date
  * 9/23/16 Deliverables due- basic board schematics and layouts
  * 12/1/16 Deliverables due- pre-final drawings, bill of materials
  * 2/15/17 First delivery of 6 CPADs
  * 3/10/17 Final delivery of 14 CPADs
  * Feb/Mar 2017 Acceptance and radiation testing
  * June/July 2017 Anticipated ISS technology demonstration (SpX-12 or similar)
  * Aug/Sep 2017: Contingent on successful verification of CPAD performance:
    @ Completion of technology demonstration analysis
    @ Preparation for operational use of CPADs on ISS
    @ Start of EM-1 certification activities

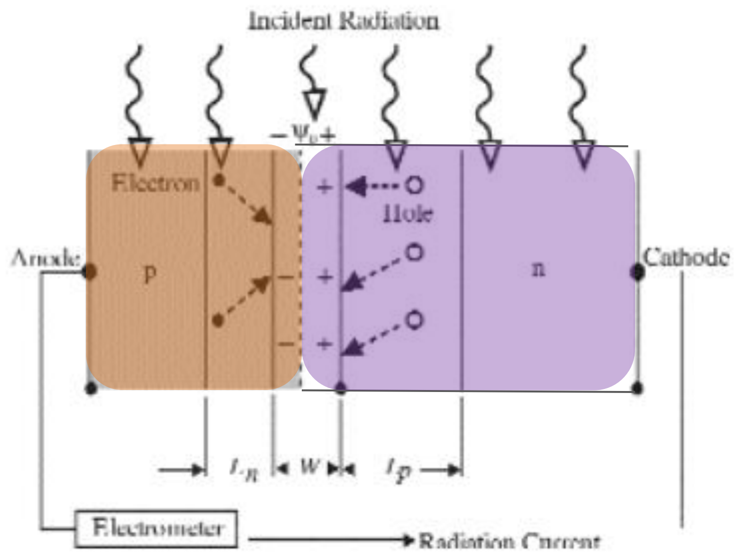
Backup

3) Technologies Overview- Si Diodes



3) Technologies Overview- Si Diodes

- Established: used for 30-40 years
- Hardware: p-n Si junction diode without external bias: depletion area forms at p-n junction
- Radiation detection: radiation creates electron-hole pairs in depletion layer;
  internal bias creates current measured for instantaneous readout



- Advantages: Compact, good sensitivity (~1-5 muGy), low power (need continuous readout), rugged packaging, simple instrumentation (low cost)
- Disadvantages: Energy (LET) dependent calibration; radiation damage changes sensitivity/calibration (kGy); response variation with temperature (0.5%/deg C)

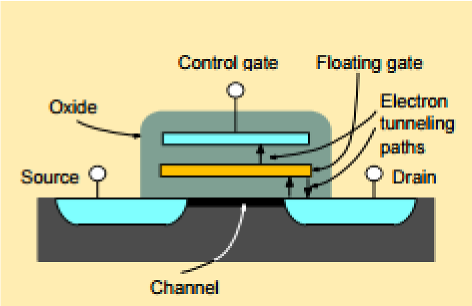
3) Technologies Overview- Direct Ion Storage

- Established: used for 20 years
- Hardware: MOSFET transistor with floating gate: stores variable amounts of charge (analog) isolated from other components (configurable); read by measuring channel conductivity/voltage of transistor between source and drain (does not disturb charge on floating gate); ion chamber on top of MOSFET
- Radiation detection:

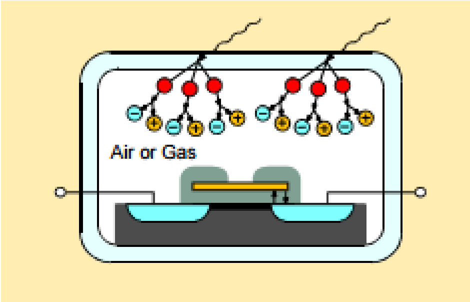
* Floating gate exposed to air/gas volume where ionizing radiation produces electron-ion pairs; electric field of bias on floating gate (~30V) collects charge carriers
* Photon response: wall material initial interaction, secondary electrons ionize air/gas
* Charged particle response: wall sufficiently thin -> deposit readable energy in air/gas

-> change dosimetric characteristics by changing wall material & thickness (few mm), gas

Standard Analog EEPROM memory cell



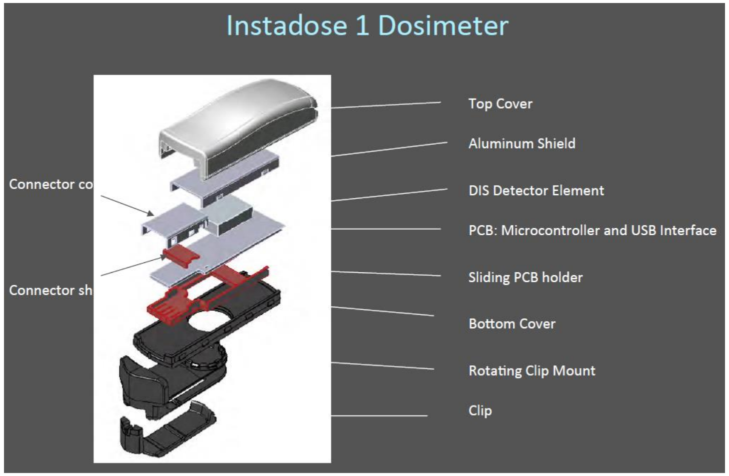
DIS memory cell



- Advantages: Compact, good sensitivity (~5-10 muGy), low power (readout only when desired), rugged components, simple instrumentation (low cost), can zero floating gate if exposed to high dose; fading <5% over 1 year, no impact of rel. humidity or temperature
- Disadvantages: Not as established as silicon diodes; calibration potentially energy/LET dependent

3) Technologies Overview- Direct Ion Storage

- Instadose 1 and 2 COTS products: licensed for dosimetry market



One DIS detector

Two DIS detectors (shallow & deep)